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Experiments on the Tranſmiſſion of Acids, and other Liquors, in the Form of Vapour, over ſeveral Subſtances in a hot earthen Tube. By Dr. JOSEPH PRIESTLEY.

Read, Dec. 20, 1799. I HAVE publiſhed an account of many experiments on the tranſmiſſion of ſteam, and alſo of acids, in the form of vapour, over ſubſtances of various kinds in hot earthen tubes, with an apparatus to receive both the air that was produced in the proceſs, and the liquor that was diſtilled. The following were made at the ſame time, but were then thought leſs worthy of publication. Some of the facts may, however, be of uſe to thoſe who may be diſpoſed to reſume thoſe experiments.

Sending the vapour of ſpirit of nitre over an ounce of *iron turnings*, I got 140 ounce meaſures of air with great rapidity. Of this no part was nitrous, or fixed, but it was ſlightly inflammable. The reſt was phlogiſticated.

In the courſe of the proceſs, the finery cinder that was formed had united to the earth of the tube, and made a hole through it, but I collected 8 dwts. of the iron which had not been much affected.

With *copper* in the ſame proceſs I got pretty pure dephlogiſticated air, from the acid only, while the production was rapid, but when it came ſlowly, it was nitrous. The copper was covered with a peculiar kind of ſcale, and ſome parts were entirely reduced to it. It was brittle, but not black.

Sending the ſame vapour over 240 grains of perfect *charcoal*, I got, with prodigious rapidity, and full of black ſmoke, 900 ounce meaſures of air, ſlightly inflammable, without any fixed air. It was of the ſame ſpecific gravity with common air, and what remained of the charcoal weighed 47 grains.

From about an ounce of the *charcoal of bones*, out of which all air had been expelled by heat, I got, by the tranſmiſſion of the ſame vapour, about an hundred ounce meaſures of air, of which one-fifth was fixed air, and the reſt phlogiſticated. Continuing the proceſs, the air that came afterwards was dephlogiſticated, from the acid only.

From a quantity of melted *lead* I got, in the ſame proceſs, air that came with great rapidity, at firſt dephlogiſticated from the acid, afterwards, what was worſe than common air, as it extinguiſhed a candle. After the proceſs I found in the earthen tube much glaſs of lead covered in part with a white powdery ſubſtance, which was, no doubt, nitrated calx of lead.

The experiment with *tin* in this proceſs was ſimilar to that with lead. After the proceſs there was found a quantity of a white ſubſtance in hard lumps, and the tin that remained was covered with it. This was, no doubt, the nitrated calx of tin.

When this proceſs was gone through with *biſmuth* the air produced was exceedingly turbid, and ſtrongly nitrous. But the

the greateſt part of the acid came over in red vapours, which were imbibed by water, that afterwards gave out nitrous air. The metal was covered with a white powdery ſubſtance, but in ſome places yellow, the nitrated calx of biſmuth. The liquor that was diſtilled was of a blue colour, and the veſſel in which it was received, was filled with red vapours.

Sending the vapour of *marine acid* over a quantity of *copper*, I got about 40 ounce meaſures of air, the greateſt part of which was ſtrongly inflammable, but mixed with common air. For when, after being turbid, it became clear, and the production ſlow, the ſtandard of the air was 1.45.

I then ſent the vapour of this acid through an empty earthen tube glazed on the outſide only, and got about 60 ounce meaſures of air of the ſtandard of 1.4, or 1.35 very turbid. The reſult was the ſame when the tube was glazed both inſide and outſide. This air I ſuſpect had been tranſmitted through the tube, while the vapour of the acid paſſed through in the contrary direction.

With this acid vapour ſent over 10 dwts. of perfect *charcoal* I got about 700 ounce meaſures of air, without any ſenſible quantity of fixed air; but afterwards one tenth of the produce was fixed air, and the reſt inflammable, of which 20 ounce meaſures weighed two grains leſs than the ſame quantity of common air. This air came over white as milk, and the acid that was diſtilled was quite black.

I ſeveral times ſent *cauſtic fixed alkali* in vapour through an earthen tube containing *iron*, when the firſt portion that was diſtilled was ſlightly acid, but not afterwards. I had the ſame reſult in three proceſſes, in which the glaſs worm, and all the apparatus, had remained juſt as it was after the preceding experiments; ſo that nothing acid could well have come to it.

Experiments made with Charcoal, Phoſphorus and Animal Fibres in the Nitrous Acid.

I have formerly given an account of experiments on the ſolution of charcoal in the nitrous acid; and as there is ſome diverſity in the reſults, it may be of uſe to add the following:

Some pieces of pounded charcoal diſſolved with difficulty in nitrous acid, but with heat it conſtantly gave air, of which about one-fifth was at firſt fixed air, and the reſt nitrous; but at laſt it was wholly phlogiſticated. At another time half of the produce was fixed air, and the reſt phlogiſticated.

From 205 grains of perfect charcoal and three ounce meaſures of ſtrong acid of nitre, I got 180 ounce meaſures of air, of which at firſt only one-ſixth, but at laſt one half, was nitrous, and the reſt fixed air. With freſh acid to the remainder of the ſame charcoal I got 82 ounce meaſures of air, of which at firſt only one-ſixth was nitrous, with equal meaſures of common air occupying the ſpace of 1.6. Of the reſt one half was more purely nitrous. The phial in which the ſolution was made becoming dry, and preſently after red hot, I got with great rapidity, and in a very turbid ſtate, 50 ounce meaſures more; and of this one half was fixed, and the remainder phlogiſticated.

Charcoal of copper appeared to differ from that of wood in that, being diſſolved in the nitrous acid, it gave only nitrous air, without any fixed air, and very little phlogiſticated air. From this it may be inferred that charcoal of copper contains no oxygen, which charcoal of wood does, and by which it can give fixed air.

The different reſults of diſſolving copper, phoſphorus, and animal fibres in the ſame quantity of the acid of nitre may give riſe to ſome uſeful obſervations.

Having

Having found that a certain quantity of nitrous acid gave 79½ ounce meaſures of nitrous air by the ſolution of copper, I put into the ſame quantity of the ſame acid as much phoſphorus as it would diſſolve, and found that it yielded 21 ounce meaſures of air, all phlogiſticated; a quantity very nearly to which the nitrous air yielded by the copper would be reduced by heating iron in it, and other phlogiſtic proceſſes. There was a ſtrong acidvapour in this phlogiſticated air, even after being long confined by water.

In the ſame quantity of the ſame nitrous acid, diluted with as much water, I diſſolved one ounce of dry boiled beef, and got from it 82 ounce meaſures of air, all phlogiſticated.

That dephlogiſticated air, or oxygen, enters into the compoſition of fixed air, I think I have proved in various ways, but moſt deciſively by heating charcoal of copper in dephlogiſticated air. From the following experiment on the heating of charcoal of wood in it, it ſeems evident that both fixed and phlogiſticated air are in part compoſed of it.

In 79 ounce meaſures of dephlogiſticated air, which with two equal meaſures of nitrous air occupied the ſpace of 0.93, I diſperſed, by means of a burning lens, 15½ grains of charcoal; when they were increaſed to 91 ounce meaſures, and by waſhing in water reduced to 53, of the ſtandard of 1.92. Again, in 74 ounce meaſures of the dephlogiſticated air, I diſperſed 13½ grains of charcoal, when it was augmented to 80 ounce meaſures, and it was diminiſhed by waſhing in water to 48.

That nitrous air contains oxygen, ſeemed probable from the burning of pyrophorus in it. The ſame may perhaps be inferred from the burning of charcoal of wood. Filling a tall glaſs jar with pure nitrous air, I placed

placed it as quickly as I could over a piece of hot charcoal, and obſerved that it burned with a conſiderable glow, much better than in common air: and the jar was filled with a white cloud. After a few minutes the air was diminiſhed to about one-fourth of its original bulk; but after remaining in this ſituation all night, it was increaſed to about one-third of the original quantity; and being then examined, it appeared to be all phlogiſticated. Dipping the ſame charcoal into water, I got from it $1\frac{1}{2}$ ounce meaſures of air, all phlogiſticated, but with a ſlight mixture of fixed air. This ſubject may deſerve farther inveſtigation. For ſince dephlogiſticated air ſo readily unites with nitrous air, and with it forms nitrous acid, it is not eaſy to account for nitrous air containing any portion of the ſame element, and retaining its aerial form. Alſo the juice of turnſole does not change its colour by ſaturation with nitrous air, which if it contained oxygen, it might be expected to do.

MISCELLANEOUS EXPERIMENTS.

1. *On the colouring of the ſolution of copper in Volatile Alkali, and of various ſubſtances in the marine acid.*

In repeating my former experiments of this kind, a few circumſtances occurred which I did not ſo particularly attend to before; and may be deſerving of notice, and of a farther proſecution. They ſhow that dephlogiſticated air is eſſential to theſe colours, and how they may be given and taken away at pleaſure.

It is well known that the ſolution of copper in cauſtic volatile alkali aſſumes a blue colour if it be made with acceſs of air. Without it, it is perfectly colourleſs; and the colour may be diſcharged by more copper, and reſtored again by means of air, as long as the menſtruum is

is capable of diſſolving the metal. The coloured liquor is alſo heavier than that which is without colour; and if a phial of the colourleſs liquor be opened, the colouring will begin at the top, and deſcend in the form of a fine thread in the center of it to the bottom, till the whole be coloured.

By means of this colourleſs ſolution 6 ounce meaſures of air were reduced to 5, completely phlogiſticated, without any fixed or inflammable air in it.

Liver of ſulphur diſcharges this colour:

The ſolution of minium, and alſo that of red precipitate, in the marine acid is attended with much heat, the former with the emiſſion of dephlogiſticated marine acid air, and the latter without it. But when the ſolution of the red precipitate is become cool, and colourleſs, it is afterwards diſſolved in this acid without any generation of heat.

The ſolution of finery cinder in this acid is not attended with heat.

The ſolution of minium has a beautiful yellow colour, but by diſſolving red precipitate it becomes colourleſs. It will alſo diſcharge any other colour made by a ſolution in this acid.

The ſolution of iron in marine acid acquires colour by acceſs of air only, and the ſolution of more iron, even that which is ruſted, will diſcharge the colour.

This coloured acid became colourleſs by diſſolving the black powder of mercury and lead. Much air was produced in this proceſs, and it was pure fixed air, with a ſmall reſiduum that extinguiſhed a candle.

An exceedingly ſmall quantity of pure air is ſufficient to reſtore colour to the ſolution of any ſubſtance in the marine acid.

2. *Of*

2. *Of the production of ſulphur by heating water impregnated with vitriolic acid air.*

When I firſt made this experiment it was a long time before any ſulphur appeared; but it is formed much ſooner when the common air is expelled from the tube by heating a little of the impregnated water previouſly to its being hermetically ſealed. By this means the ſulphur will appear the firſt day, and in three or four days the production will have attained its maximum, the whole tube being covered with white cryſtals. After ſome days there will be a little ball of yellow ſulphur ſwimming on the middle of the liquor, and a good deal of ſulphur will be found at the bottom of it, by the cryſtals on the ſides continually ſliding down into the liquor, as others are formed. The tubes I have generally uſed for this purpoſe are ſomething more than three feet long, and more than half an inch wide.

Sulphur is produced in the very ſame manner and in the ſame time by means of water impregnated with hepatic air. The only difference that I obſerved was that I did not ſee the ſame dancing vapour in this proceſs as in that with vitriolic acid air, which is a curious circumſtance in the experiment.

Having evaporated to dryneſs a quantity of water impregnated with hepatic air, there remained a black powder, like ethiops mineral. When this ſaturation is made with water confined by mercury, it has a white colour.

Opening a tube in which ſulphur had been formed from water impregnated with vitriolic acid air under water, I found the air within it of the ſtandard of 1.6, without fixed air, or any thing inflammable in it.

3. *An experiment with Papin's Digeſter.*

Aided by heat in this inſtrument a ſolution of cauſtic alkali made a *liquor ſilicum* with pounded flint glaſs.

4. *Of*

4. *Of Phoſphoric air.*

Phoſphoric air, though confined by mercury, will not always retain its property of taking fire by the admiſſion of atmoſpheric air. A quantity of this air which was made the 18th of November would not take fire on the 22d, but burned with a lambent yellow flame on the approach of a lighted candle, ſmelling ſtrongly of phoſphorus. At other times I have found this air retain its peculiar property much longer; but it was always changed to a lambent inflammable air by keeping, nor would heat reſtore it.

5. *Of the purity or impurity of airs in various circumſtances.*

Some experiments ſeem to indicate that ſomething poſitive is communicated to ſeveral ſubſtances, ſolid and fluid, in conſequence of being expoſed to heat. At leaſt they are diſpoſed after this to attract pure air from the atmoſphere, like other ſubſtances during the emiſſion of phlogiſton. The following obſervations may ſerve to throw ſome light on this ſubject, and perhaps deſerve to be proſecuted farther.

Air from water freſh diſtilled, from rain water, or freſh ſpring water, gave out air ſomething worſe than that which had been expoſed to the atmoſphere.

Air from ſnow water, from a ſolution of blue vitriol, and from water diſtilled from this ſolution, gave air a little worſe than water long expoſed to the atmoſphere. Such alſo was air from river water during a flood from late rains.

Putting a ſmall quantity of ſpirit of wine into a phial, and covering it with a ſmall glaſs veſſel ſtanding in water, I found the air within it conſiderably leſs pure than common air.

Air incumbent on water impregnated with nitrous vapour extinguiſhed a candle.

A phial which had contained aqua regia ſaturated with gold having a very pungent ſmell, I examined the air within it, and found it to be of the ſtandard of 1.65, much worſe than common air.

Air which had been confined with *muſk* was a little worſe than common air. There was no fixed air in it. Air confined in a ſimilar phial, and with a ſimilar cork, about the ſame time was not worſe than common air, nor was air confined with camphor.

Water in which liver of ſulphur was diſſolved did not give out air worſe than before.

6. *Of the proportion of latent heat in ſome kinds of air.*

That heat is neceſſary to the aerial form of ſubſtances is as evident as that it is neceſſary to form the vapour of water. I took the following method to aſcertain the proportional quantity of latent heat in thoſe kinds of air which are readily abſorbed by water, expecting to find a conſiderable difference between them, but I did not find any. I incloſed the bulb of a mercurial thermometer in one end of a glaſs tube, and made the place air-tight with a cork and cement; then filling the tube with mercury, I introduced a certain quantity of water, which, ſurrounding the bulb of the thermometer, would ſoon impart to it whatever heat it received by the abſorption of the air that was thrown up into it.

The quantity of water in all the experiments was 44 grains, and the jar of air that I threw up into it held nearly two ounce meaſures. The kinds of air on which I made the experiment were marine acid air, vitriolic acid air, and alkaline air. In all the caſes the abſorption of the air raiſed the thermometer four degrees of Fahrenheit, which was a ſpace of an inch and a half; ſo that a ſmall difference would eaſily have been perceived. The vitriolic acid air required a little agitation, and on this

this account the heat would not be communicated ſo ſpeedily, and conſequently ſome would be loſt. But the difference in this caſe was only that of 1.6 and 1.5.

7. *Experiments relating to aqua regia and the ſolution of gold and platina in it.*

In impregnating marine acid with nitrous vapour, which makes an aqua regia much ſtronger than that which is made by a mixture of two acids, there dropped from the end of the tube through which the phlogiſticated vapour was conveyed a deep green acid, in the form of balls, which fell to the bottom of the veſſel, and after continuing a ſhort time burſt with the emiſſion of air, the green colour then diſappearing and the acid gradually aſſuming its proper orange colour.

Going to make uſe of a quantity of aqua regia that had been made ſome months, I found its colour changed, and that, by the eſcape of the nitrous vapour, it was become mere marine acid. Impregnating it again with nitrous vapour, it was the ſame as before. Diſtilling the ſolutions of gold and platina in this compound acid, the liquor that came over was marine acid. Platina required more heat to diſſolve it than gold.

8. I made the following experiments to obſerve the different effects of phlogiſticated and dephlogiſticated nitrous acid in the ſolution of mercury.

In the dephlogiſticated acid an ounce of mercury gave leſs of both nitrous and dephlogiſticated air. I diſſolved an ounce of mercury in dephlogiſticated acid of nitre, and without changing the retort, which was cooled, and gradually expoſed to a red heat till nothing more came over, I got about 15 ounce meaſures of nitrous air, and 55 of dephlogiſticated. From the calx that was ſublimed I got 17 ounce meaſures of dephlogiſticated air. In the ſame proceſs with phlogiſticated nitrous acid I got 43 ounce meaſures of nitrous air, and 63 of de-

phlogiſticated; and from the calx that ſublimed I got 6 ounce meaſures of nitrous air, and 15 of dephlogiſticated.

9. That quicklime gets weight by expoſure to the air is well known. The following experiment will ſhew what that weight is.

An ounce of quicklime expoſed in a ſhallow diſh on the 1ſt of July increaſed in weight till the 14th of Oct. when it had gained 320 grains. Another ounce had gained 300 grains in the ſame time, and after this they gained nothing more. In the ſame time an ounce of quicklime ſaturated with water, and then left to dry, had gained 294 grains: another ounce gained exactly the ſame weight, and a third 325 grains.

10. Pyrophorus is generally made with the charcoal of vegetable or animal ſubſtances mixed with alum, or any thing that contains the acid of vitriol, and the heat by which it takes fire is occaſioned by the eager attraction of this acid for water. I accidentally found that a pyrophorus may be made of ſulphur and iron.

Having kept a cup full of this mixture made up with water in a quantity of common air about two months, I then took it out, and left it in the cup. The next day perceiving the cup to be warm, I emptied it upon a board, when it grew hot, ſmoked very much, gave out a ſtrong ſmell of vitriolic acid air, and at length became red hot. Putting a part of it into another cup confined by common air, the air was rapidly diminiſhed.

11. *Of the abſorption of fixed air by a mixture of iron filings and ſulphur.*

Among ſome of the firſt of my experiments were ſome on the effect of this mixture on fixed air, as well as on that of the atmoſphere. The following relate to the ſame ſubject, and may deſerve to be proſecuted further.

A mixture of this kind which had been ſome time in common air, and was become brown, abſorbed fixed air with great rapidity, without leaving any ſenſible reſiduum. But different portions of it abſorbed this air very differently. Six ounce meaſures of fixed air which had been a long time expoſed to about an ounce of ruſted iron had now a reſiduum of about three-fourths of an ounce meaſure, and it was wholly phlogiſticated.

A bladder containing about 20 ounce meaſures of fixed air was connected with an earthen tube in which were pieces of iron, and at the other end of the tube was another bladder, but empty. The middle part of the tube being made red hot, the bladder was preſſed, ſo as to make the air paſs through the hot iron, and thence it was driven back again, and the proceſs repeated till the air was reduced to 6 ounce meaſures, and by waſhing in water to 5. It was ſlightly inflammable.